Applying systems approach to driver behaviour analysis

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***Abstract*— Driver behaviour is an important subject in road safety research. Investigations into this subject have often been conducted using qualitative and statistical methods. However, due to the temporal and spatial gap between actions and their consequences in real life, this paper argues that these methods are not the most suitable approaches to understanding and dealing with this safety problem. In the first instance, these methods tend to identify a sequential course of action and treat causal factors linearly. In contrast, this paper suggests the use of systems analysis and causal loop diagramming which help to view a system holistically as well as identify the circular nature of processes in a system. In this way, it often becomes unimportant to identify a factor as a cause or an effect. This paper goes further to demonstrate the use of this analysis method with the risky behaviour of commercial motorcycle drivers. It concludes by showing that a combination of actions will be more suitable than a sequential policy implementation being currently adopted in dealing with this safety problem.**

***Index Terms*— causal loop, commercial motorcycles, driver behaviour, systems analysis**

I. INTRODUCTION

Drivers' risk taking attitude has been noted in various studies on road safety. It is however more interesting that the motivations for this attitude is diverse. For example, [1] report that there is a higher probability that those who use alcohol would behave more risky. Similarly, [2] agree with the body of knowledge indicating that the use of drugs increases the risk of a driver being involved in a collision. [3] find that drivers' experience and training tend to increase risk threshold of drivers while drivers' level of education is inversely proportional to their risk taking attitude. These and many other studies confirm the wide range of the motivations for risky driver behaviour. Nevertheless, identifying how to deal with this attitude is still a subject of ongoing research. For example, [4] observe that intervention measures often adopted to improve behaviour can be counterproductive, especially when it raises risk threshold without changing the risk perception of intervention recipients. These findings underline the complexity with risk-taking attitude of drivers. They also create avenues for further research into risky driving and how to deal with it.

A special group of drivers who are more vulnerable and characterised with this risky attitude are motorcycle drivers. Motorcycle drivers even in developed countries such as the UK have been described as "thrill seekers" who are usually risky on the roadway [5]. Similarly, [6] finds that motorcycle drivers in Indonesia are very unsafe in their use of the road way. Several other studies support this claim about motorcycle drivers in general ([7], for example). But a more risky group of motorcycle drivers is the group of commercial motorcycle drivers. Commercial motorcycle drivers are those who use motorcycles to transport passengers for a fare. Various studies indicate that these drivers exhibit more high risk behaviours than other motorcycle drivers [8]; [9]. For example, [8] observe that commercial motorcycle drivers are particularly notorious for wilfully violating traffic laws on the road. Similarly, [9] found that commercial motorcycle drivers who belong to the trade's association have a higher probability of violating traffic laws (– indicating that commercial motorcycle drivers generally have less compliance than other motorcycle drivers). Notwithstanding, as with drivers in general, they have their motivations for their risky behaviour. These motivations have been described in the literature too: [10] indicate that most drivers are ill-prepared for the job, lacking in necessary training and driving skills. Similarly, [11] shows that drivers' motorcycle's expensive acquisition mode might be another factor contributing to the problem. In addition, [12] found out that the problem of trust between regulators and drivers made regulatory effort difficult. Earlier, [13] indicated that successful regulatory measures targeted at this transport might be elusive when there is inadequate understanding about the operation. This multi- and inter-related factors characteristics can be an indication to a sort of details complexity. But it also an indication of dynamic complexity as causes and their effects may not apparently follow a sequence but may be separated in time [14]. An attempt to improve understanding through the adoption of a systems analysis method using causal loop diagramming might be able to deal with this complexity. This is as causal loop method is able to deal with both detailed and dynamic complexity in any problematic situation.

II. SYSTEMS APPROACH AND CAUSAL LOOP DIAGRAM METHOD

Systems approach is preferred to other analysis method. It is an approach that shows the connections between the elements of a system. As noted by [15] systems approach helps to see the bigger picture of challenging situations so as to be able to develop solutions that are more reliable. In a way, it can help to understand a challenging situation better. [16] for example, asked the rhetorical question: "Do we actually have adequate models of accident causation in the present dynamic society?" He went further to note that the "socio-technical system involved in risk management includes several levels ranging from … managers and work planners, to system operators". (p.183). He suggests that, for example, the characteristic of drivers can result from the pressures they are subjected to. Defining system characteristics based on drivers' characteristics alone without considering the interaction with other system components might make the solution proffered less effective. (a good example of this is captured in [12])

Speaking further in this vein, [17] argues that models should not just treat safety events and conditions; rather, the process involved should be treated. This process, according to him, controls a sequence of events and describes system and human behaviour over time. He concludes that safety in a system can be maintained when the process leading to safety compromise is constrained to operate within safety limits. Thus it is not about preventing an event from occurring in the system; it is about maintaining the characteristics of a safe system. Statistical methods are, however, unable to provide these details. This wider analytical opportunity provided by systems approach prompted [18] to note that systems approach to understanding safety problems in socio-technical systems provides a deeper understanding of how dynamic, complex system behaviour affect safety. This demonstrates the superior capacity of systems approach over most conventional methods.

Systems approach usually makes use of causal loops analysis, amidst others. Causal loops are a type of causal networks. Causal networks are representations used to depict how causes are related to their effect. They are used for analysis in various academic and professional fields and adopt various names, graphical representations, and applications. They are a useful instrument to easily relate and transparently illustrate causes and their effect [19]. They also enhance a systematic analysis of processes or events in a manner that many other methods of analysis such as mathematical or descriptive methods cannot provide. Causal networks include digraphs, causal loop diagram, tree diagram, flow diagram, and Bayesian network, amidst others. However, of all these, only a causal loop network is able to represent causal analysis in a manner that the feedback processes within a system are clearly presented. Causal loop diagrams are able to chart the circular nature of cause and effect and map system behaviour over time. They use three basic processes to achieve these: reinforcing feedback, balancing feedback and delays [20]. Some of these processes will be further explored subsequently. Before this exploration, a simple description of the case study adopted for analysis in this paper is presented.

III. PROBLEM DESCRIPTION

Commercial motorcycle transport is a transport mode widely acknowledged for its benefits which includes speed, door-to-door service, and access to remote places and narrow roads. They also play an important role as gap filler as well as a source of employment for people [21], [22], [23], [24], [25]. For example, [24] describe them as helping with the problem of infrastructural gap and serving areas where there are no alternative transport modes. [22] note that their speed and door-to-door service are an advantage to them. [23] indicates that the problems of poorly developed road network, narrow streets, traffic congestions, and poor standard of public transport all combine to position commercial motorcycles as gap filler. In his own word, [21] (p.59) describes commercial motorcycle drivers as "nowadays enhance(ing) the physical and social mobility of others and themselves". Nevertheless, commercial motorcycle operation comes with its challenges.

One of the main challenges of commercial motorcycle operation well reported in the literature is safety problem [23], [26], [27], [28], [29]. Reference [23] reports that commercial motorcycles were regarded as necessary evil in Cameroon where they were notorious for causing numerous accidents due to their reckless and dangerous driving. Reference [30] indicates that the rise in the use of commercial motorcycles in Brazil coincided with the rise in road crashes. In Nigeria, accident is the most commonly reported challenge faced by motorcycles in general and commercial motorcycles in particular: motorcycle share of road crashes in Nigeria is between 19% and 25% while their share of fatality is as high as 33% [31], [32], [33]. Furthermore, [34] shows that as many as 56% of drivers randomly interviewed have been previously involved in at least a crash. One underlying issue about this safety problem in Nigeria is the attitude of these commercial motorcycle drivers to safety issues [32]. The analysis of this safety problem using systems approach is now presented.

IV. SYSTEM ANALYSIS

A Data: source and type

To explore the subject of safety in commercial motorcycle operation, a study was conducted to identify factors that influence commercial motorcycle drivers' safe operations and their relationship with one another. This agrees with [35] who acknowledged that driver behaviour is now becoming recognised as a major target for safety interventions. This study involved conducting a semi-structured interview with stakeholders in commercial motorcycle operation. These stakeholders included the drivers, the traffic laws enforcement agencies, hospital accident and emergency staff, and other researchers on road safety. The interview data was analysed using qualitative methods to obtain a story-like description of the processes that characterise commercial motorcycle safety. This description is presented below. In the description, the phrases in italics are factors named in the analyses:

"Enforcement capacity which represents the combined ability of traffic enforcement agencies in the study location affected several other items. It was found that whenever there were more officers on patrol, fewer drivers worked due to increased *probability of detection* of a violation by enforcement officers. This was more so as more monitoring by officers meant more spending on fines and bribery for the drivers. Thus, more *violations* led to more *enforcement capacity* which led to reduced *drivers' income*. Notwithstanding, there were times an increase was noted in *violations*. This was because *violations* offered some financial benefits too (increased *drivers' income*). Whenever violations increased, more officers were drafted to increase *enforcement capacity* and match the problem. This obviously would result in increase in the *probability of detection* and violation would go down. It was also noted that some drivers were naturally deterred (*deterrence*) from violating laws due to increased likelihood of being arrested. In this way, increasing *enforcement capacity* could reduce the total number of *violation*.

Meanwhile, the increasing size of *enforcement capacity* was also proliferating *corrupt practices* among officers. This was the reason for the drivers' habit of *dodging arrest* after they had committed. *Corrupt practices* influenced *deterrence* and *prosecution rate*, making both very low. But both *deterrence* and *prosecution rate* were affected by *political influence* too. It was noted that politicians used commercial motorcycle

drivers in political campaigns and often defended them whenever they violated traffic laws.

Thus, *political influence* was seen as contributing to *violations*. Moreover, because *deterrence* and *prosecution rate* were low, the level of *violations* was high. The consequence of high *violations* was *accidents*. Between 60% and 85% of accidents were blamed on violations. But other things caused accident too. *Dodging arrest*, for example, often resulted in *accident*. *Dodging arrest* was blamed on drivers' *spending aversion/ cutting corners* and *violations*, in addition to other factors. Other causes of *accidents* included *other road users*, the *risky road environment* in the study area, and *alcohol and other drug use*. *Other road users* were particularly blamed for the *risky road environment*. In addition, the increasing *number of drivers* meant that the number of *accidents* had been increasing since more people were getting exposed to road risks.

Whenever an accident happened, it resulted in loss of life or/and damage to properties which meant less of *drivers' income*. It was found that these *accident* losses could caution drivers to reduce their *violations*. Many other things however affected drivers' tendency for *violations*. These included the increasing number of less cautious drivers. These were called *risky and dangerous drivers*: they joined commercial motorcycle trade untrained and unqualified, and highly *ignorant* of traffic rules. In addition, *alcohol and drug use* amidst drivers as well as drivers' *earning pressure* affected *violations*. *Earning pressure* was the outcome of the desire to make a target amount (*target income*) by a driver each day. Finally, as the *number of drivers* increased, so was the number of *violations* committed.

The rising *number of drivers* was caused by many factors. The main one was *high job returns*. For example, it was found that most drivers started with *hire-purchase and rent options* and paid off all credit within a year indicating that the interest to take these expensive options was related to drivers' ability to pay back quickly (*high job returns*). The availability of *hire-purchase and rent options* thus supported drivers' population growth. In addition, politicians (*political influence*) distributed motorcycles at times to youths many of which eventually became commercial motorcycles. This distribution of motorcycles by politicians therefore was contributing to *risky and dangerous driving*. The increasing *number of drivers* also contributed to some other problems: it was increasing *competition between drivers*; *competition between drivers* led to a reduction in *drivers' income*. It was also increasing the number of *risky and dangerousdrivers* since the trade has *free and easy entry* structure and inefficient *enforcement capacity*. Particularly, many of new drivers were *ignorant* of safety rules and *inexperienced* in driving a motorcycle. Notwithstanding, they worked hard and set high *target income* which necessitates working more, using *alcohol and other drugs*, and not having time to *participate in training*. All these put together made drivers *risky and dangerous*.

Furthermore, the increasing *number of drivers* was also increasing the number of drivers who took motorcycles on *hire-purchase and rent*. This *hire-purchase and rent* was increasing drivers' population as well as raising cumulative drivers' *target income*. As earlier shown, *hire-purchase and rent* was due to the *high job returns* characteristic of the trade. But *high job returns* in commercial motorcycle trade depended on the ability of the driver to work hard. Drivers therefore worked hard to make high *drivers' income* and so maintained the *high job returns* characteristic of the trade. They did this by setting high *target income* which put pressure on them while working. This is *earning pressure*. The high *target income* was also as a result of the need to pay for *hire-purchase and rent* and the *thrift savings* drivers engaged with.

As noted, drivers did use *alcohol and other drugs*. They often used them because of *peer influence*, *inclement weather* and the need to work more (when additional capacity for work was required). Whenever they used *alcohol and other drugs*, they increased their ability to work (*work capacity*), and were able to increase their (*drivers'*) *income*. But their need to work more was usually caused by the pressure to earn more (*earning pressure*). This *earning pressure* therefore promoted *thrift savings* in some ways: because drivers worked under pressure, they saw the trade as too strenuous and planned to switch to easier trades as quickly as possible. So they would decide to save money and raise some capital for another trade. This raised their *target income* and *earning pressure* further and increased the need to work more (*additional work capacity requirement*) in a vicious cycle.

Similarly, as the *additional work capacity requirement* (the need to work more so as to earn more) increased, drivers worked more. If their *additional work capacity requirement* rose, they would need to increase their *work capacity*. They would then spend more time working and would have less spare time available to them. The combination of *ignorance* about driving requirements and less *available spare time* were responsible in some instances for low willingness to give *time for training* which caused many of the drivers to jettison *participation in training*. Thus it was shown that there were fewer trained (those who had ever *participated in training*) drivers now than there were when the population of *drivers* was small. *Ignorance* and *participation in training* fed back to one another: *ignorance* made some drivers think they did not need training. Not participating in training reinforced ignorance too by making drivers believe they could do without it. However, one other factor contributed to low *participation in training* – the lack of training opportunities for motorcycle drivers (*availability of training opportunity*).

Finally, drivers who set high *target income* might delay essential vehicle maintenance, showing a trait of *spending aversion/ cutting corners*. Such drivers did not possess necessary vehicle/driver's documents either and would want to *dodge officers*" [36].

B Typical system processes

From this narrative, the operation of the drivers and how this affects their safety characteristics are now used to described the dynamics of operation of commercial motorcycles.

1. Floating goal design of enforcement system

The enforcement system reflects a reactive system. Traffic management (denoted by enforcement capacity) responds to perception about the state of traffic decorum (taken as targeting an acceptable level of traffic decorum). This acceptable level is however changing as the enforcement system becomes aware of its inability to meet up. For example, traffic officers (earlier in the history of commercial motorcycle operation) treated them as illegal transport. As they became more acceptable, the enforcement system attempted to enforce measures such as compelling drivers to acquire vehicle and drivers' license. Similarly, measures such as eradicating vehicle overloading has also been previously enforced. In 2009, a policy to compel the use of crash helmet was inaugurated. But none of these measures has been successfully implemented. Thus the goal of the enforcement system is floating as it keeps changing with reality. In a sense, this reflects the characteristics of the system as one with no stable policy. Fig. 1 illustrates this floating goal system. It shows that officers are drafted (*enforcement coverage*) to manage traffic with a target level of traffic decorum. This traffic decorum is guided by the factor *probability of detection*. *Probability of detection* is a measure of how often a violating driver gets away with committing a violation; the level of violations changes in response to this factor.

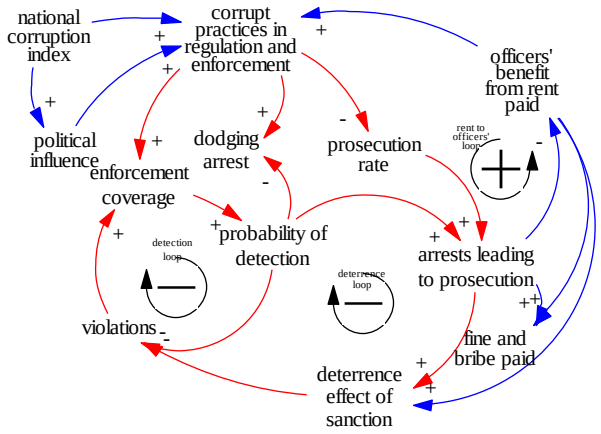

Fig. 1: Floating goal loops of enforcement capacity (coverage)

(This figure is taken from [36])

Moreover, *probability of detection* is not the only factor that affects *violations*. Some others do. One of these is the *deterrence effect of sanction*. This *deterrence* is the outcome of arrest and prosecution for violations; it is the attitude that drivers have towards violations. The higher the *probability of detection*, the higher the *deterrence effect* should be. This however, might not be the case in a situation where drivers do not face the full consequence of violation. As shown in the figure, deterrence is affect by *prosecution rate*. *Prosecution rate* is affected by the *corrupt practices* amidst the traffic officers. In this case, *prosecution rate* is low. Because *prosecution rate* is low, *deterrence* is low too and *violation* is higher than it should be: Thus this process also reflects the effect of the challenge of corrupt practices in enforcement operation. This is in addition to the policy gap that is responsible for the floating goal and allows the officers to be compromised.

2 Reinforcing loops of the drivers' characteristics

Another factor that contributes to *violations* is the personality the drivers develop in the trade. This is described by the factor labelled *risky and dangerous drivers*. As shown in fig. 2, commercial motorcycle trade is a fast growing trade with high population growth rate. This high growth rate is partly supported by *high job return*[1] as well as the availability of easy motorcycle acquisition schemes. Fig. 2 shows that *drivers population growth* loop is a cycle where the *awareness of high job return* is responsible for the increasing *number of drivers*. This is more so with the support of motorcycle acquisition schemes (i.e., *hire purchase and rent*) and the *ease of joining the trade*. This growing population is however increasing *competition* (*for passenger*) in the system and growing pressure of work (called *earning pressure*). This pressure is complicated by repayment demand that results from the expensive motorcycle acquisition schemes (*hire purchase and rent*) some drivers take. It is this *earning pressure* that forces drivers to take risky actions in order to break even in the business [32]. Thus drivers are usually under pressure to take risks and commit violations.

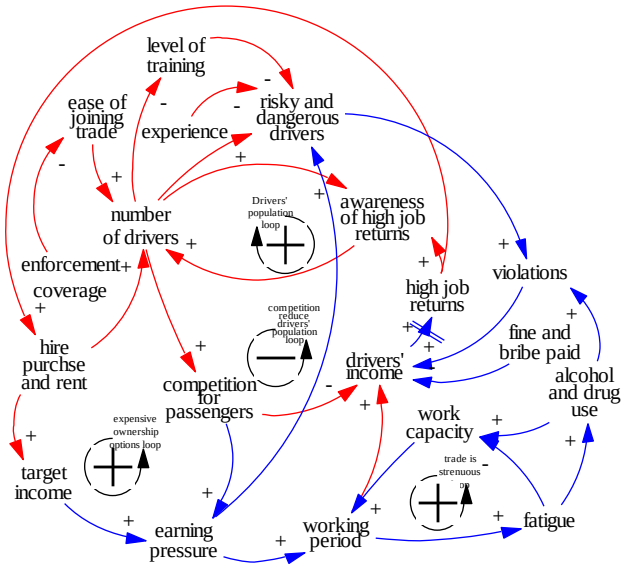

Fig. 2: Reinforcing loops of risky and dangerous drivers

(This figure is taken from [36])

A close look at fig. 2 shows that three of the four factors (i.e., other than *experience*) contributes to growing level of *risky and dangerous drivers*. *Experience* is gained slowly and is therefore expected to have a weak effect. The other three factors are growing in a reinforcing manner. It can therefore be argued that the level of *risky and dangerous driver* is growing. Introducing some measures of organisation and coordination into the recruitment of drivers and the manner their motorcycles are acquired may be necessary to break the increasing strength of *risky and dangerous driver*. This might be a way to reduce *violations*.

C Leverage

As shown by [20] systems analysis can more easily help to identify points of leverage. To improve safety in commercial motorcycle operation, dealing with the processes that precipitate risky behaviour is essential. First, developing an

[1] this is intended to mean the trade's ability to sustain livelihood

inclusive policy to guide operation in commercial motorcycle trade would be more efficient than periodic arbitrary policy decisions. This step might help to break the cycle of floating goal the enforcement system has been subjected to. This is more so as this trade is generally regarded as informal and unregulated. Similarly, an all-inclusive guiding policy may be better able to deal with the problem of corruption as the interest of all the parties involved in the trade can be treated in such a policy document. In this sense, the loops of *detection*, *deterrence* and *rent to officers* in fig. 1 would be broken.

Similarly, it is easier to identify leverage points in fig. 2. As discussed earlier, the reinforcing loops contributing to *risky and dangerous drivers* can be weakened once they are identified. One of the ways to do this is a licensing policy that not only certifies prospective drivers but also slows down their population growth. Such policy would break the loop of *drivers' population growth*. In addition, it is good to organise this trade in a manner that protects new drivers from *expensive repayment schemes* and break the loop of *expensive ownership options*. This is important as it reduces the pressure on new drivers and prevent the early development of unsafe behaviours in the bid to meet up with tight demands. By addressing these problems identified in the system, it is possible to obtain a more sane commercial motorcycle transport.

V. CONCLUSION

This paper has shown the importance of systems analysis in dealing with difficult systems. It has shown that this analysis method is able to expose the *behaviour shaping processes* within a system so as to provide an avenue for an improved decision making process in dealing with the problem. It also shows that taking a linear approach to solving a problem by sequentially addressing a symptom at a time may not offer an improved system. Rather, a combination of solutions is often required to break the processes that generate the problem. For example, in the case study treated, it is clear that the drivers are doing what they think can sustain them in business. At the same time, the enforcement system is making effort to respond to the problem. But the systemic structure pushes the effort of both sides to promote risky behaviour. The use of a systems analysis helps to see all these clearly and to identify where interventions might best be successful.

Despite the analytical ability of systems analysis, its benefit still depends on the usefulness of its product. This is more so that all models are wrong [37] and a model is only of value if it is useful. A causal loop analysis may not be of any value if it does not provide for a clearer understanding of the system being analysed. The competence of the modeller and the clarity of the analytical process adopted are therefore important to obtaining a useful model.

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